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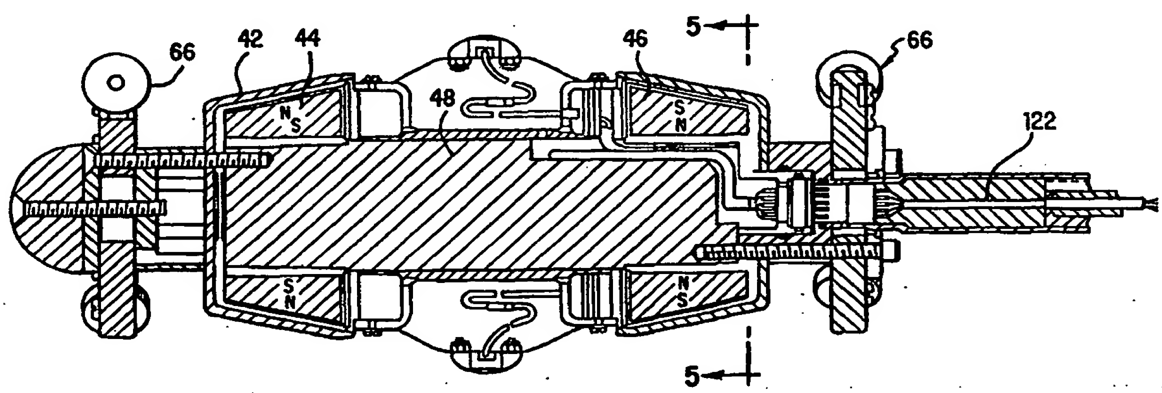
(54) Title: SYSTEM FOR INSPECTING IN–SERVICE GAS DISTRIBUTION MAINS



(57) Abstract

A system for inspecting in–service gas distribution mains is disclosed. Coiled tubing technology and magnetic flux leakage (MFL) technology are integrated to produce a new inspection system for low pressure, in–service distribution pipelines. The coiled tubing provides the means by which an inspection module employing MFL technology is inserted into, moved through, and removed from an in–service pipeline. A portable inspection system can thereby be moved to a desired location on a trailer. The sensor module comprises a plurality of magnet assemblies each having a Magnet N out, a Magnet S out and a magnet core, the magnet assemblies being conical in shape and being arranged into a circular array. The magnet array diameter is smaller than that of a pipe to be inspected, thus defining a radial air gap. The magnet array being constructed and arranged to provide a magnetic circuit having sufficient strength so as to be operable through the radial air gap. A centering mechanism is constructed and arranged to maintain the sensor module in concentric relation with the pipe to be inspected. This array provides an efficient method of packing the magnets to generate the very powerful magnetic field desired. The conical shape of the magnets in this assembly permits the unit to negotiate tighter bends than would be possible with a cylindrical assembly. The centering mechanism permits product bypass and minimizes removal of surface debris.

SYSTEM FOR INSPECTING IN-SERVICE GAS DISTRIBUTION MAINS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to a system for inspecting low pressure, low flow distribution pipelines for defects in structural integrity used in the natural gas pipeline distribution field.

DESCRIPTION OF PRIOR ART

There are hundreds of thousands of miles of low pressure, low flow steel distribution pipelines currently in operation. All pipelines are prone to time dependent defects, such as corrosion, which can reduce safety, undermine security of service and threaten the environment if failure occurs. Prudent operators recognized the need to inspect these pipelines to ensure that affected locations are repaired or replaced before failure occurs.

In the mid-1960's, systems were developed to inspect high pressure transmission pipelines. These inspection devices are commonly referred to as "pigs" ("intelligent pigs," "smart pigs"). While there are several technologies currently used for this inspection application, the first developed, and still the most common, is that of Magnetic Flux Leakage (MFL). However, these have heretofore only been used on a frequent and reliable basis in high-pressure environments. Thus, there has been a need for an inspection system developed for low pressure distribution pipelines that exploits MFL technology.

Traditional pipeline inspection tools are free swimming devices that travel through the pipeline with the flowing product. A seal is formed to the wall of the pipeline by flexible cups attached to the tool. A differential pressure across this sealed cup creates the force preferred to propel the tool. Magnetic flux leakage inspection tools generally have two or more segments coupled together by a flexible joint.

The MFL inspection technique is well established and generally easy to apply in high pressure applications. It comprises inducing a high level magnetic field into the wall of the pipeline under inspection and scanning the inside surface with a magnetic sensor to detect variations in the magnetic field caused by wall thinning defects or other imperfections or features which change the expected magnetic properties of the material.

A typical MFL inspection tool contains a magnetic section to induce a

may reside on the pipe wall.

Still another problem associated with systems for inspecting in-service gas distribution mains that precede the present invention is that many of them are not small and flexible enough to be inserted into the main through the off-take.

An even further problem associated with systems for inspecting in-service gas distribution mains that precede the present invention is that many of them do not operate at sufficiently low power levels to be certified for gas operation.

Another problem associated with systems for inspecting in-service gas distribution mains that precede the present invention is that many of them do not provide a method of gaining access to the pipeline to be inspected under live conditions.

Yet another problem associated with systems for inspecting in-service gas distribution mains that precede the present invention is that many of them are not insertable into the pipeline through a side off-take.

Still a further problem associated with systems for inspecting in-service gas distribution mains that precede the present invention is that many of them comprise an inspection module which cannot be propelled through the pipeline and withdrawn from the pipeline at a single location.

Another problem associated with systems for inspecting in-service gas distribution mains that precede the present invention is that many of them do not facilitate bi-directional operation from a single entry point in the pipeline.

A further problem associated with systems for inspecting in-service gas distribution mains that precede the present invention is that many of them are not portable to allow operation in congested city areas.

An additional problem associated with systems for inspecting in-service gas distribution mains that precede the present invention is that many of them do not provide for a rapid inspection.

Yet another problem associated with systems for inspecting in-service gas distribution mains that precede the present invention is that many of them do not furnish inspection data available in real time.

For the foregoing reasons, there has been defined a long felt and unsolved need for a system for inspecting in-service gas distribution mains that can be propelled

and normal pipe bends.

An even further object of the present invention is to provide a system for inspecting in-service gas distribution mains that operates at sufficiently low power levels to be certified for gas operation.

An additional object of the present invention is to provide a system for inspecting in-service gas distribution mains that provides a method of gaining access to the pipeline to be inspected under live conditions.

Still another object of the present invention is to provide a system for inspecting in-service gas distribution mains that is insertable into the pipeline.

Yet another object of the present invention is to provide a system for inspecting in-service gas distribution mains having an inspection module thereof that can be propelled through the pipeline and withdrawn from the pipeline at a single location.

A further object of the present invention is to provide a system for inspecting in-service gas distribution mains that facilitates bi-directional operation from a single entry point in the pipeline.

An even further object of the present invention is to provide a system for inspecting in-service gas distribution mains that is portable to allow operation in congested city areas.

An additional object of the present invention is to provide a system for inspecting in-service gas distribution mains that provides for a rapid inspection.

Yet another object of the present invention is to provide a system for inspecting in-service gas distribution mains that furnishes inspection data available in real time.

These and other objects, advantages and features of the present invention will be apparent from the detailed description that follows.

DESCRIPTION OF THE DRAWINGS

In the detailed description that follows, reference will be made to the following figures:

Fig. 1 is a side, perspective view illustrating a preferred embodiment of a system for inspecting in-service gas distribution mains.

Fig. 2 is a cross-sectional view illustrating a magnetic flux leakage module

used in a preferred embodiment of a system for inspecting in-service gas distribution mains.

Fig. 18 is a cross-sectional view of the apparatus shown in Fig. 17 as seen along the line 18-18.

Fig. 19 is a cross-sectional view of the apparatus shown in Fig. 17 as seen along the line 19-19.

Fig. 20 is a side, cut-away view illustrating a portion of a preferred embodiment of a system for inspecting in-service gas distribution mains showing dual risers for non-intersecting holes.

Fig. 21 is a side, cut-away view illustrating a portion of a preferred embodiment of a system for inspecting in-service gas distribution mains showing dual risers for intersecting holes.

Fig. 22 is a side, cut-away view illustrating a portion of a preferred embodiment of a system for inspecting in-service gas distribution mains showing dual intersecting risers for non-intersecting holes.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 illustrates a first embodiment of the system for inspecting in-service gas distribution mains. As shown, coiled tubing technology and magnetic flux leakage (MFL) technology are integrated to produce a new inspection system for low pressure, low flow, in-service distribution pipelines. The coiled tubing provides the means by which an inspection module employing MFL technology is inserted into, moved through, and removed from an in-service pipeline. Thus, a portable inspection system 30 can be moved to a desired location on a trailer 32. Inspection of the pipeline 34 is accomplished by coiled tubing 36 which is provided with the MFL module 40. The inspection system 30 of in-service gas distribution pipelines 34 is more fully described as follows.

Referring now to Figs. 2 through 4, the MFL sensor module 40 is shown in more detail. The magnet assembly 42 comprises a Magnet N out 44, a Magnet S out 46 and a core 48. The magnet diameter 50 is approximately one inch smaller than that of the pipe 34 to be inspected. The magnetic circuit must operate through the ½ inch radial air gap 54 thus defined.

The air gap 54 is preferred for two reasons. First, it eliminates scraping of the magnet 50 with the pipe wall, as is commonly experienced when applying this technology.

sensor elements 90. This high density sensor array 62 collects precise magnetic data. In the preferred embodiment, the sensors 90 are integrated Hall elements (HGT 2100), currently available from Lake Shore Cryotronics of Westerville, Ohio, having preferred sensitivity and low operating current.

The mounting springs 86 permit bi-directional operation and apply minimum pressure to the sensor housing 88, which preferably can slide smoothly along the pipe wall and allow maximum product by-pass. The sensor housing 88 provides a two point contact with the pipe wall to improve stability and minimize abrasion.

To understand the design parameters of the data acquisition system, it is necessary to assess the means for propelling the inspection module 40 through the pipeline. Since the pressure and flow in the pipeline are inadequate to propel the tool 40 conventionally, an alternative propulsion structure 100 is provided. As shown in Figs. 8 and 9, coiled tubing 112 is provided. A spool 110 of tubing 112 is typically constructed of stainless steel or composite rod, and can be pushed or pulled through pipe 34 by a hydraulic power unit 116.

To provide real time analyses, the magnetic inspection module 40 is electrically and mechanically linked to data acquisition systems above ground by a flexible tube member 118. Conductors 122 (shown in Fig. 4) are contained within the tube 112, and conduct data from the sensors electronic processing cards (not shown) to the above-ground data acquisition computer (not shown), and power the sensors 90, as well. As described above, the module 40 contains thirty-two sensors 90. Each sensor 90 is a 4-terminal "bare" element wherein two conductors are required for DC bias and two conductors are required for signal. The signal outputs are preferably buffered and amplified before further processing, thereby necessitating providing a printed circuit card having thirty-two buffer amplifiers. Rather than handle each sensor individually, which would require at least thirty-two conductors for sensor signals and additional conductors for power and signal ground, a more efficient structure is provided.

By adding a second printed circuit card, all thirty-two buffer outputs are fed into a 32 channel multiplexer. Each channel is selected in turn, and all sensor channels are thereby transmitted through a single conductor. An address generator is provided which is strobed from the data acquisition computer. When the address generator receives a strobe

As illustrated by Figs. 14 through 19, insertion techniques and hardware are disclosed which enable gaining access to the in-service pipeline 34, performing the MFL inspection process and restoring the gas main to its original strength. A template 202 or weld-on clamp is preferably attached to the existing gas main 34 to provide a platform for inspection and restoration operations. Attaching the template 202 requires full circumferential excavation around the gas main 34. The two halves 204 of a split template assembly 202 are welded onto steel gas mains or bolted onto cast iron mains. Full encirclement of the main 34 is preferred.

In the preferred embodiment, the template 202 comprises a top assembly 208 fitted with one or two short length wye entry tubes 210 at a 15 to 20 degree angle to the main 34 and a lower section 212 which fits directly onto the main 34. These two elements 210, 212 are welded to the main 34 prior to cutting the access hole(s) 214. A flange assembly 216 is attached to the top of each wye tube 210 for subsequent attachment of a full bore gate valve 218 and for sealing the gas main 34 after the inspection is completed. The 20 degree wye fittings 210 are pre-made onto the top template 202. The only field welding comprises two linear welds joining the sides of the template 202 to each other and to the gas main 34, and two circumferential welds at the ends of the template 202. The height of the left-in-place template 202 is 8 inches above the main 34, which should pose no operational problems.

The template 202 provides superior support to the gas main 34 due to its longer bearing length. Since the template is installed prior to drilling the hole, all bending stresses in the main will be absorbed by the template mounting. Consequently, no residual stresses will be present to deform the pipe when the original material is weakened by cutting. Thus, the total template bearing length provides enough stiffness to counter the reduced stiffness at the cut location.

As shown in Figs. 20 through 22, three entry variations are available to effect insertion of the module. The first of these, dual risers for use with non-intersecting holes, is shown in Fig. 20. The holes do not intersect so each is drilled independent of the other. Drilling single holes has no known impact on hole saw life and assures consistent retrieval of the coupon. This application is 39 inches long and requires an excavation of 10.4 feet in length to inspect a 3 ft. deep gas main.

As shown in Fig. 21, dual riser for use with intersecting holes can be utilized.

metal hole saws as the cutting element. Bi-metal hole saws cut a very narrow kerf and therefore remove very little material. This results in very high drilling rates as well as minimal horsepower requirements. Additionally, the cost of the hole saws is very low, permitting use of a new hole saw in each new application.

In one embodiment, the hole saw contacts the gas main 34 at an angle. The minimum angle required to use steel tubing is a 20 degree template riser angle in 4" mains. The hole saw assembly is powered by hydraulics. The motor is coupled to the bi-metal hole saw by a drive shaft assembly. Bit weight is applied to the hole saw by connecting a manual jack screw to the hydraulic motor body. This design allows the operator direct tactile response for how much bit load to apply. It also prevents breakage of the hole saw.

Once the inspection has been completed, the MFL inspection device 40 is removed from the riser 234 with the valve 214 closed. The template 202 is designed to be left in place and can be re-entered at a later date when follow-up inspection is desired. To remove the lower valve, the template riser should first be sealed so that no gas escapes. This is accomplished by setting an expandable plug in the bore of the riser before removing the valve. The setting assembly requires the same hardware as the hole saw assembly with the exception that the bit load mechanism is removed. A long-handle setting tool is used to manually expand the plug. Once the plug is set, the operator can remove the valve and close the template riser with a blind seal flange. The blind seal flange provides a second, redundant seal and enables the main to be re-entered in the future without blowing gas because it allows attachment of the gate valve/launch tube assembly prior to the removal of the expandable seal plug.

Thus, a system for inspecting in-service gas distribution mains is disclosed. A sensor module for use in a system for inspecting in-service gas distribution mains comprises a plurality of magnet assemblies each having a Magnet N out, a Magnet S out and a magnet core, the magnet assemblies being conical in shape and being arranged into a circular array. The magnet array diameter is smaller than that of a pipe to be inspected, thus defining a radial air gap. The magnet array being constructed and arranged to provide a magnetic circuit having sufficient strength so as to be operable through the radial air gap. A centering mechanism is constructed and arranged to maintain the sensor module in concentric relation with the pipe to be inspected.

CLAIMS

I CLAIM:

1. A sensor module for use in a system for inspecting in-service gas distribution mains comprising:

a plurality of magnet assemblies each having a Magnet N out, a Magnet S out and a magnet core, the magnet assemblies being conical in shape and being arranged into a circular array;

the magnet array diameter being smaller than that of a pipe to be inspected, thus defining a radial air gap;

the magnet array being constructed and arranged to provide a magnetic circuit having sufficient strength so as to be operable through the radial air gap; and

a centering mechanism constructed and arranged to maintain the sensor module in concentric relation with the pipe to be inspected.

2. A sensor module as set forth in Claim 1, wherein the centering mechanism comprises a flexible disk having a diameter approximately equal to the magnet array diameter and a plurality of wheels mounted in fixed relation to the disk.

3. A sensor module as set forth in Claim 2, wherein the wheels are arranged in radially symmetric, spaced apart relation and disposed outwardly away from the center of the disk; the outermost extension of the wheels thereby defining an outer working diameter; the outer working diameter being slightly less than but approximately equal to the inner diameter of the pipe to be inspected.

4. A sensor module as set forth in Claim 2, wherein the flexible disk is constructed of a material selected to provide sufficient flexibility to the disk to permit the sensor module to negotiate bore changes in the pipe to be inspected.

5. A sensor module as set forth in Claim 4, wherein the flexible disk is constructed of urethane.

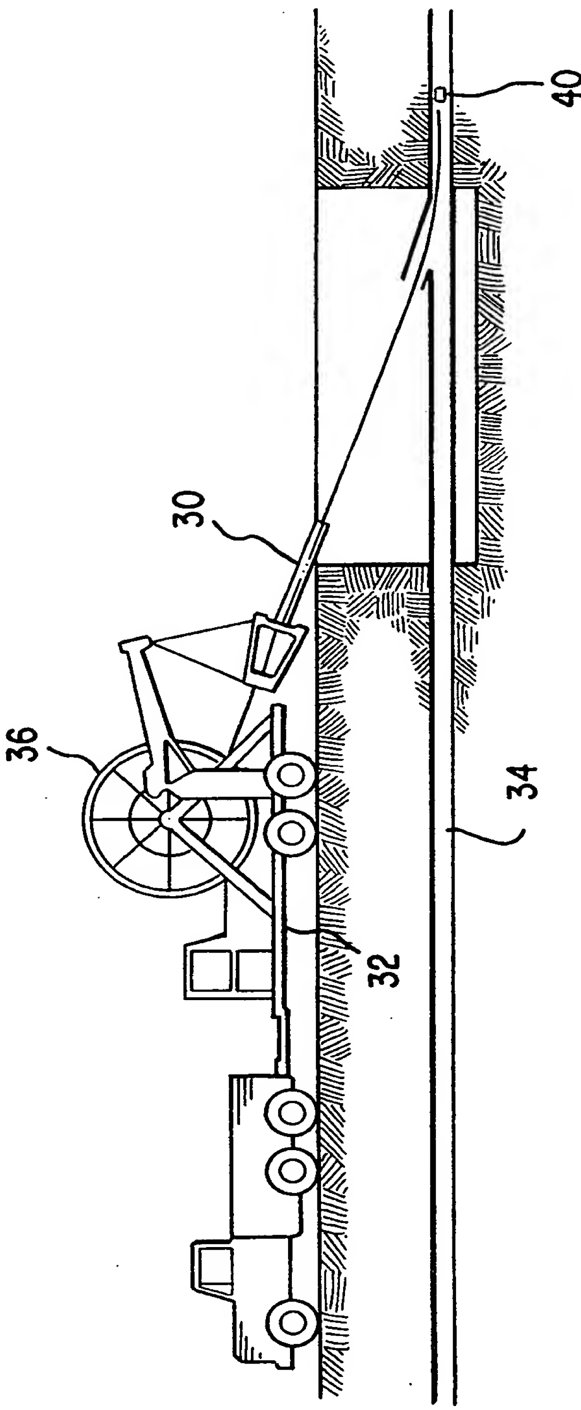


FIG. 1

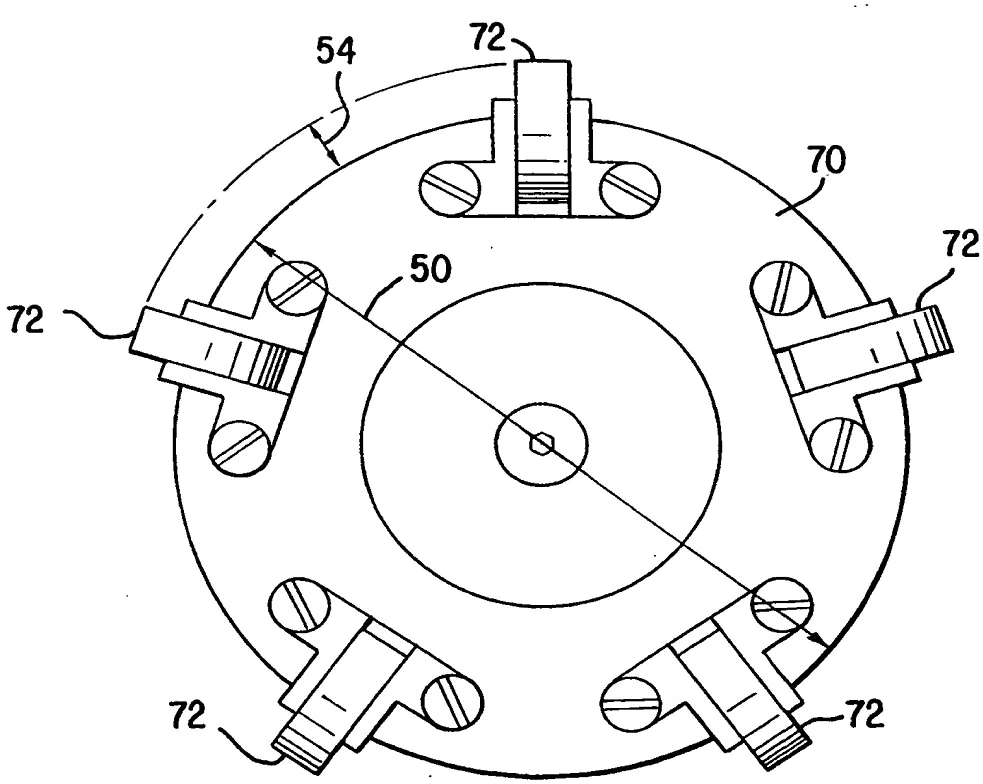


FIG. 2

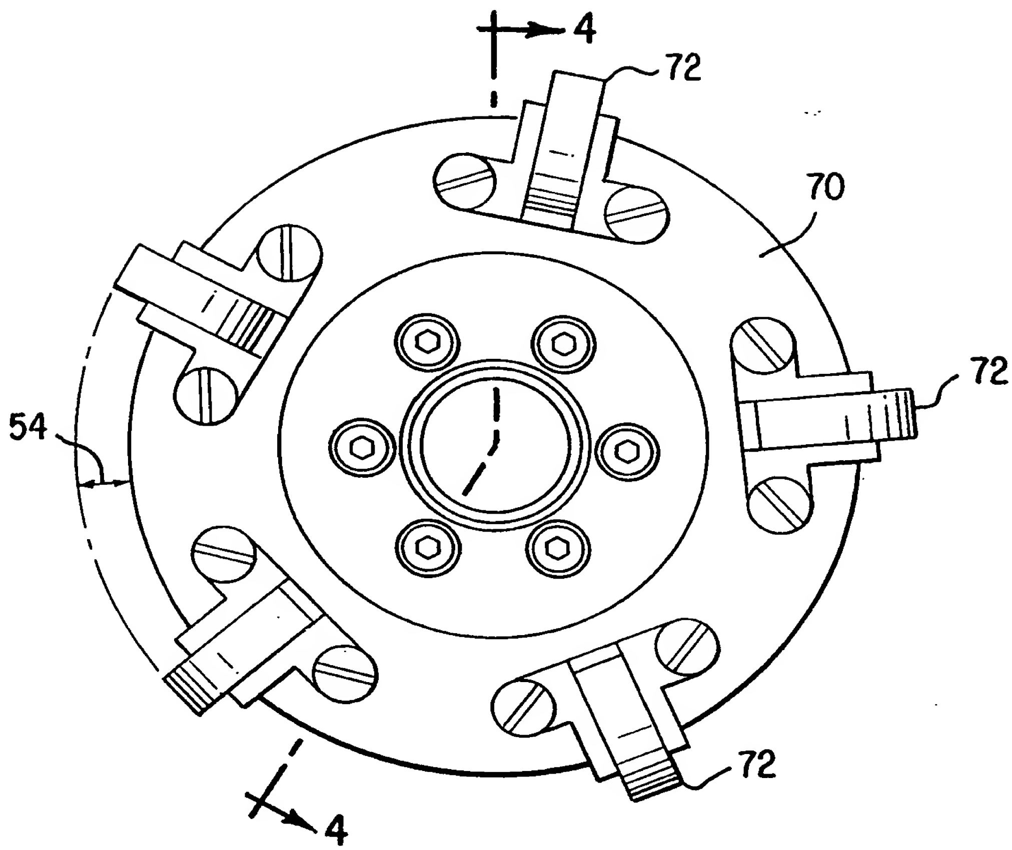


FIG. 3

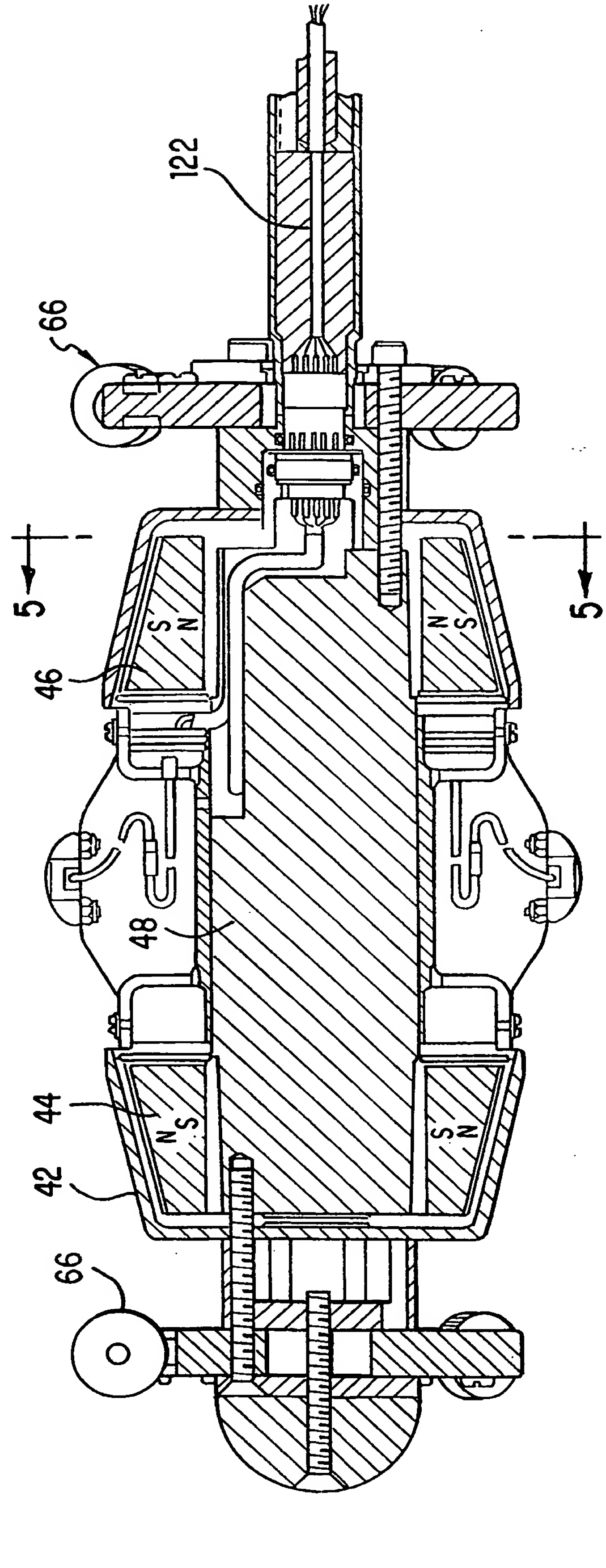


FIG. 4

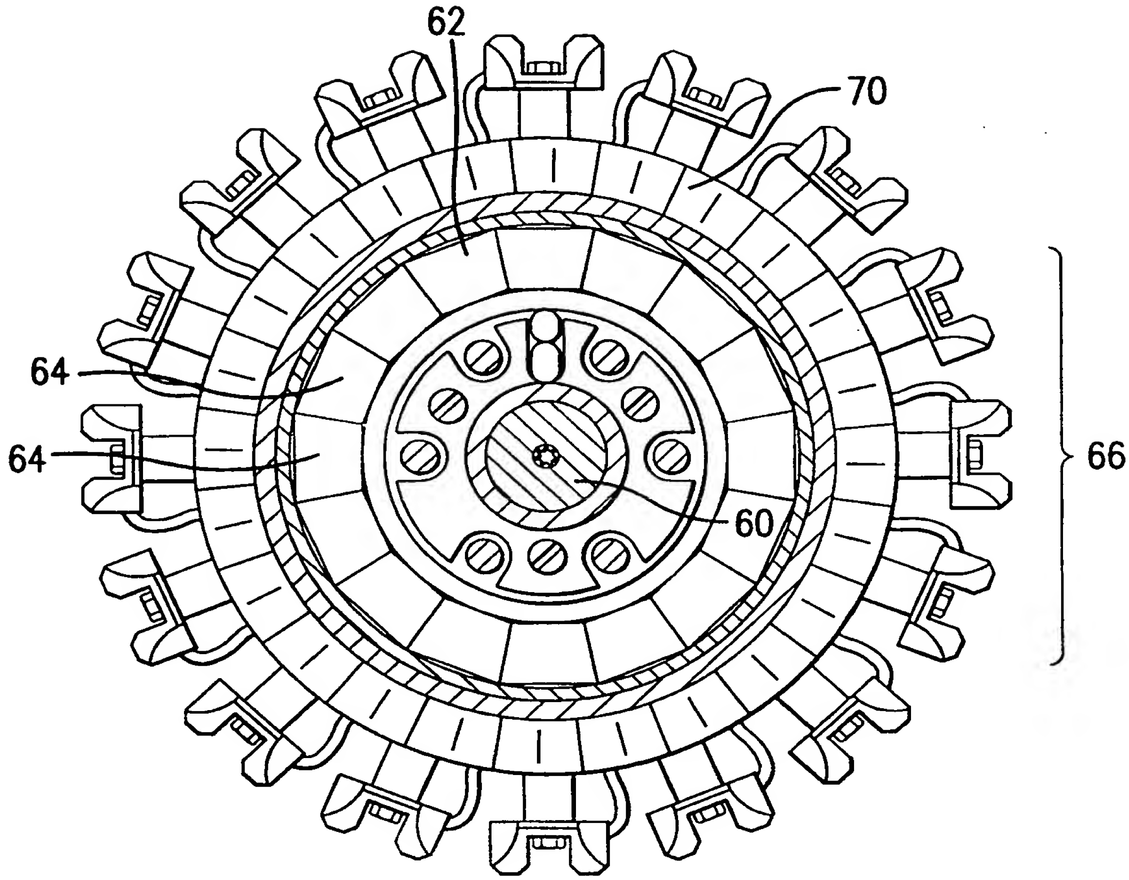


FIG.5

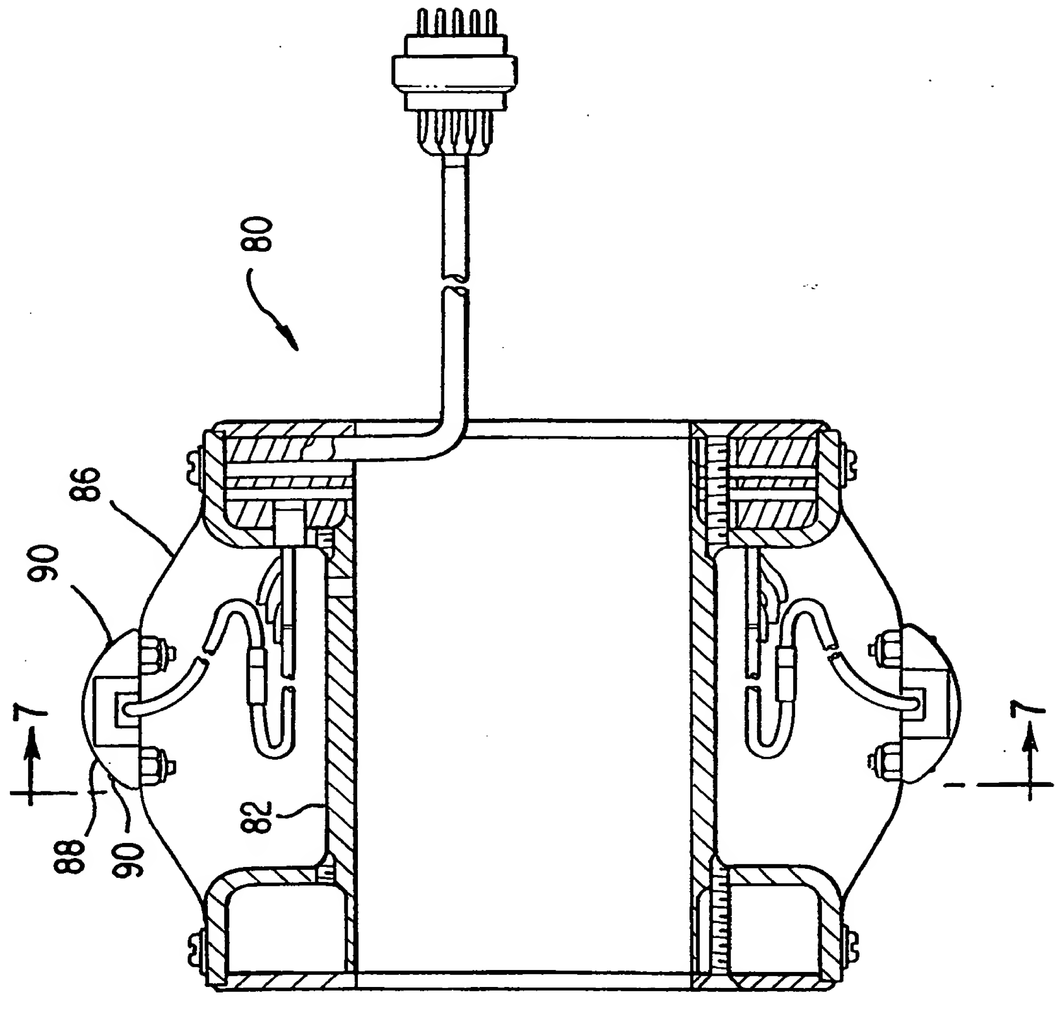


FIG.6

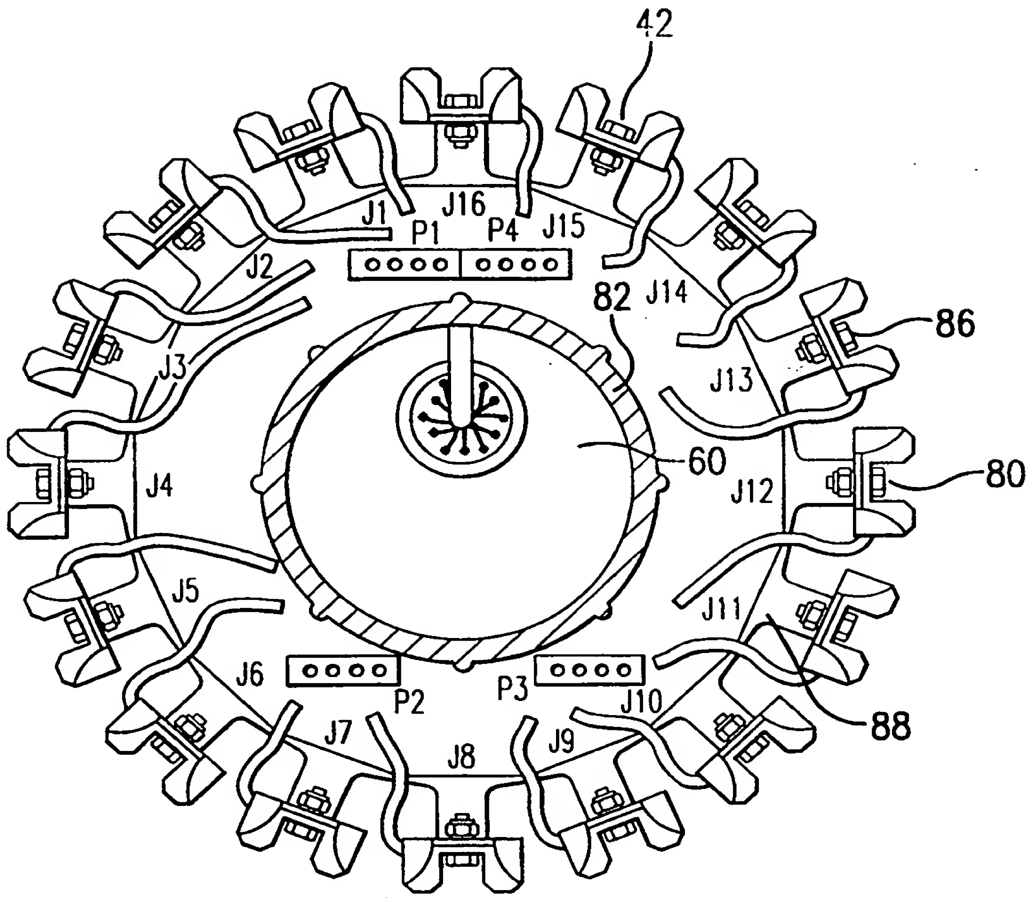

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FIG.7

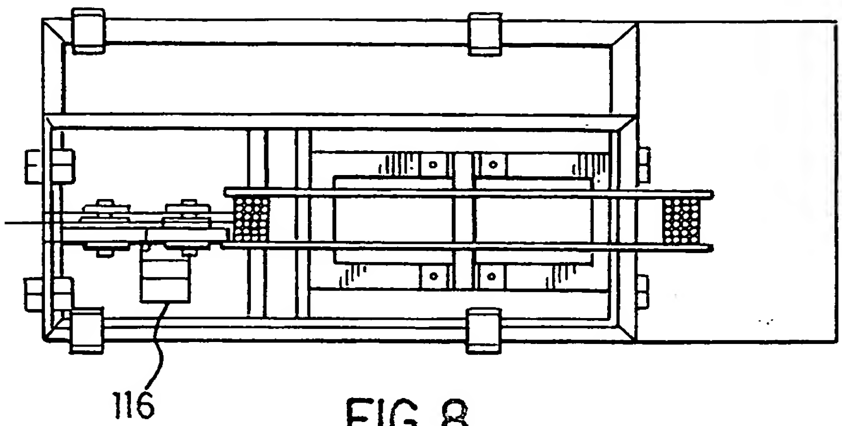

FIG. 8

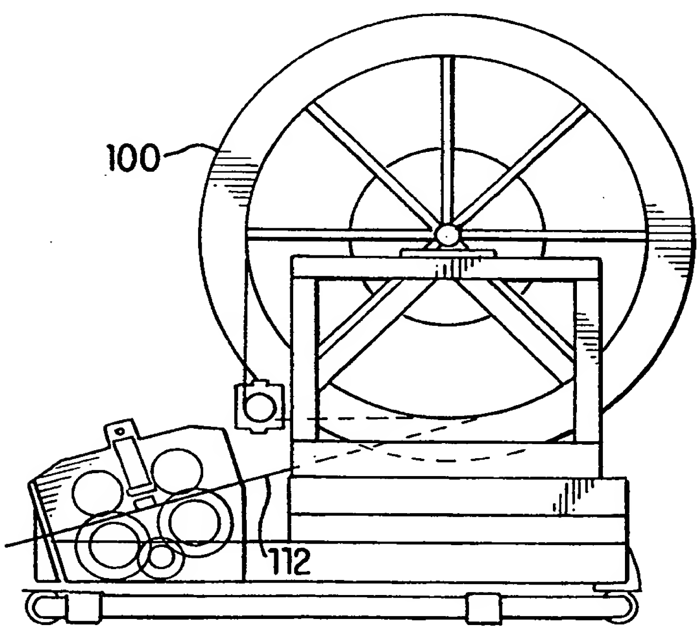

FIG. 9

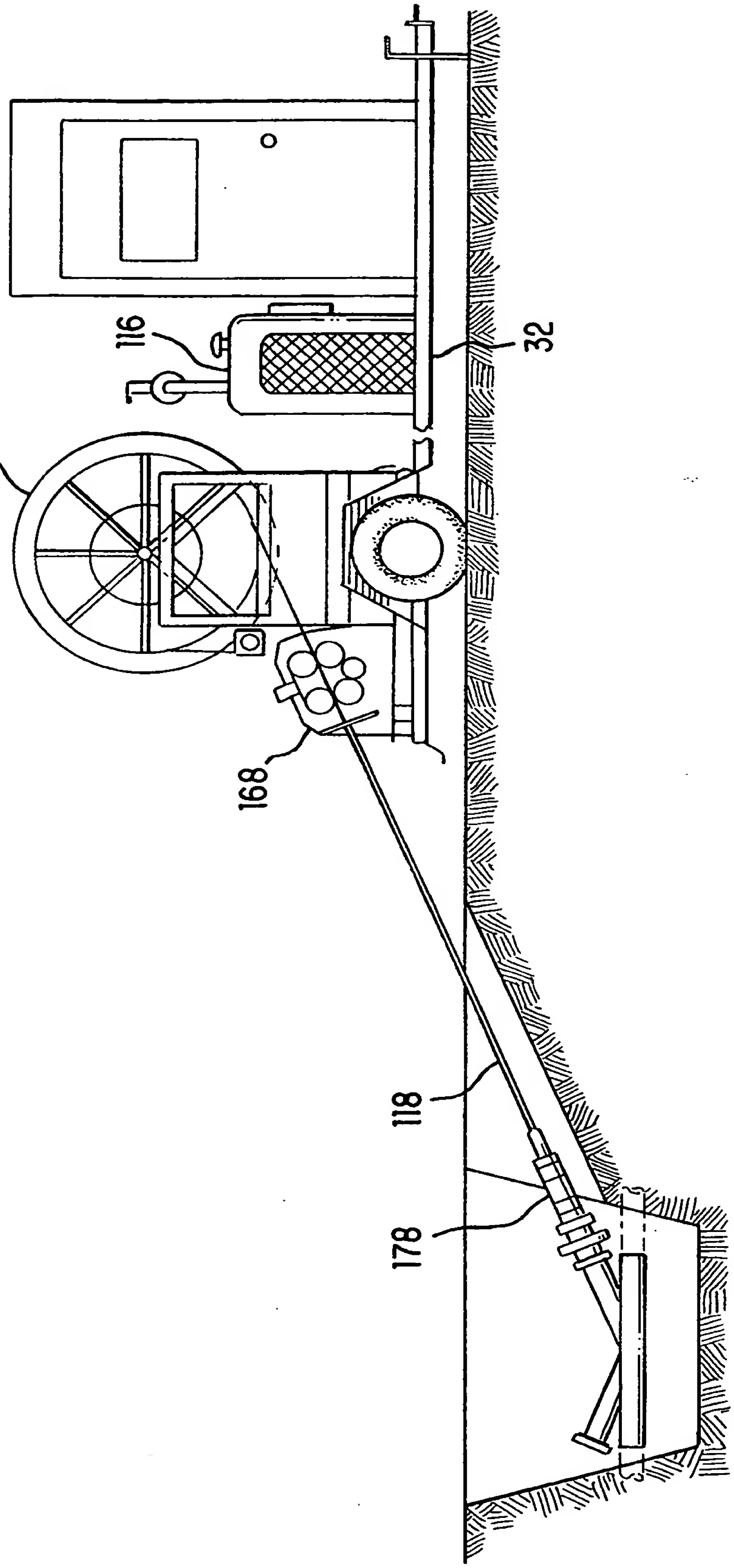

FIG. 10

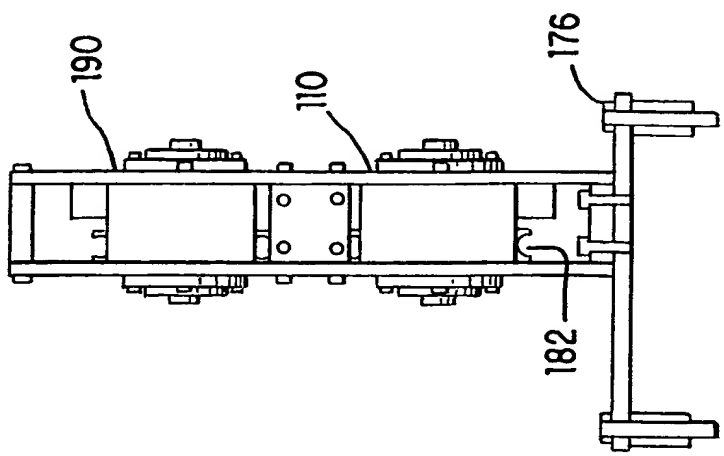

FIG.13

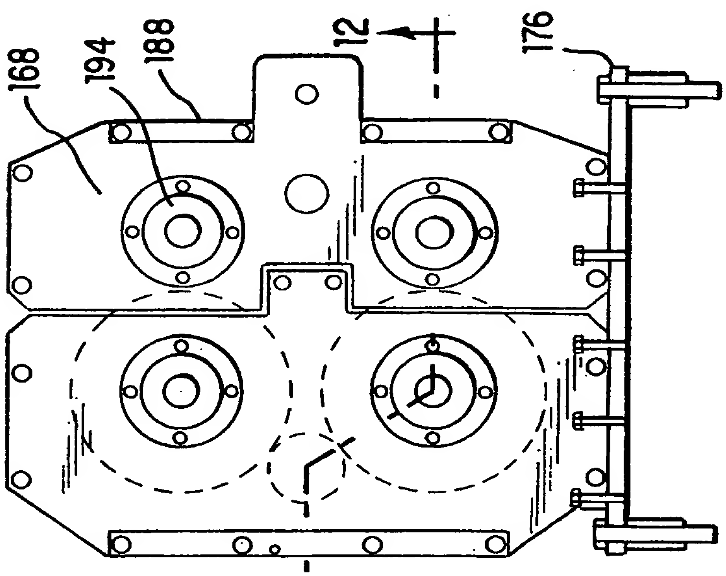

FIG.11

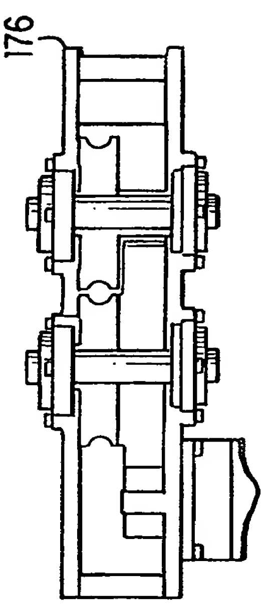

FIG.12

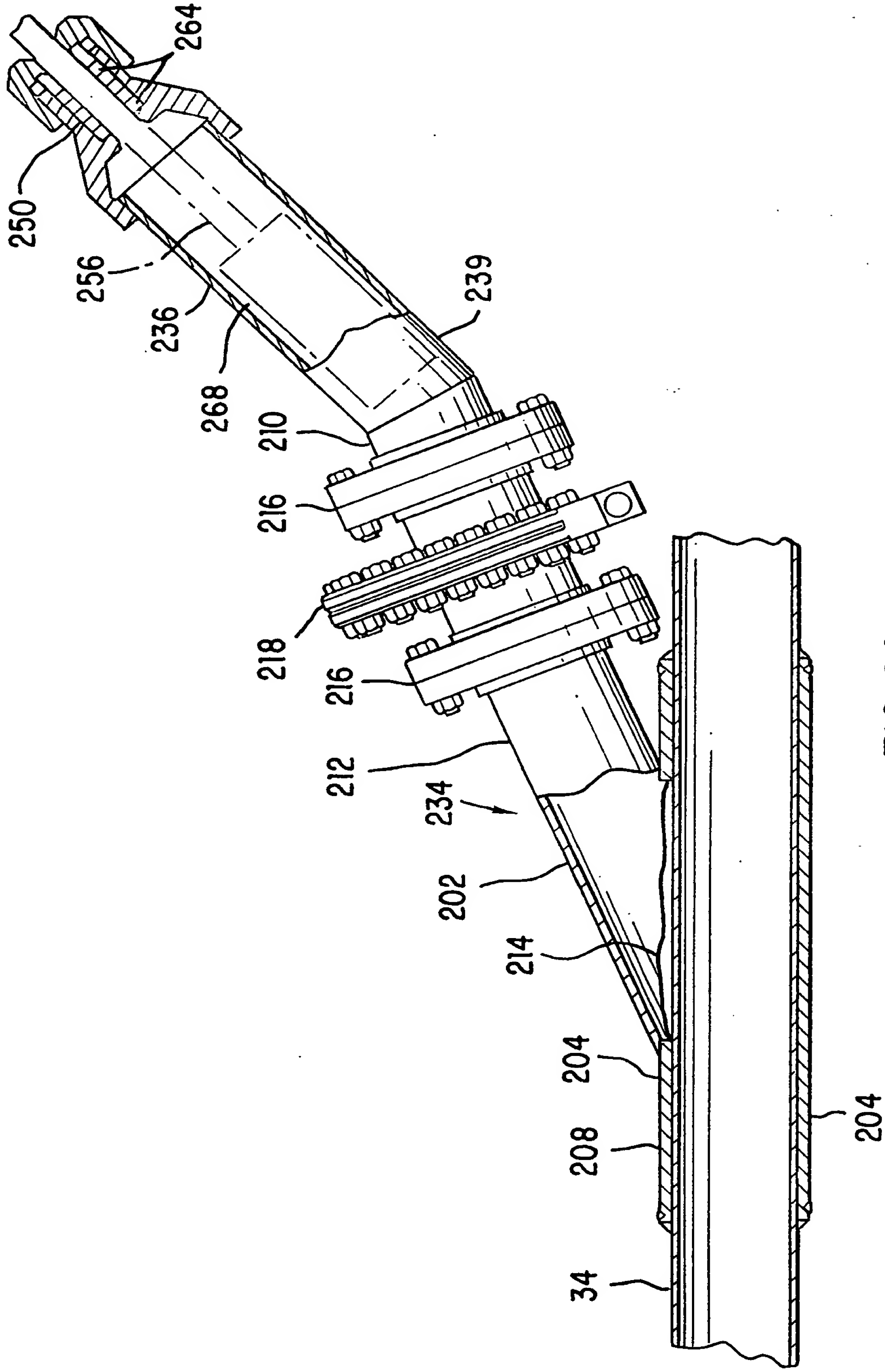
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FIG. 14

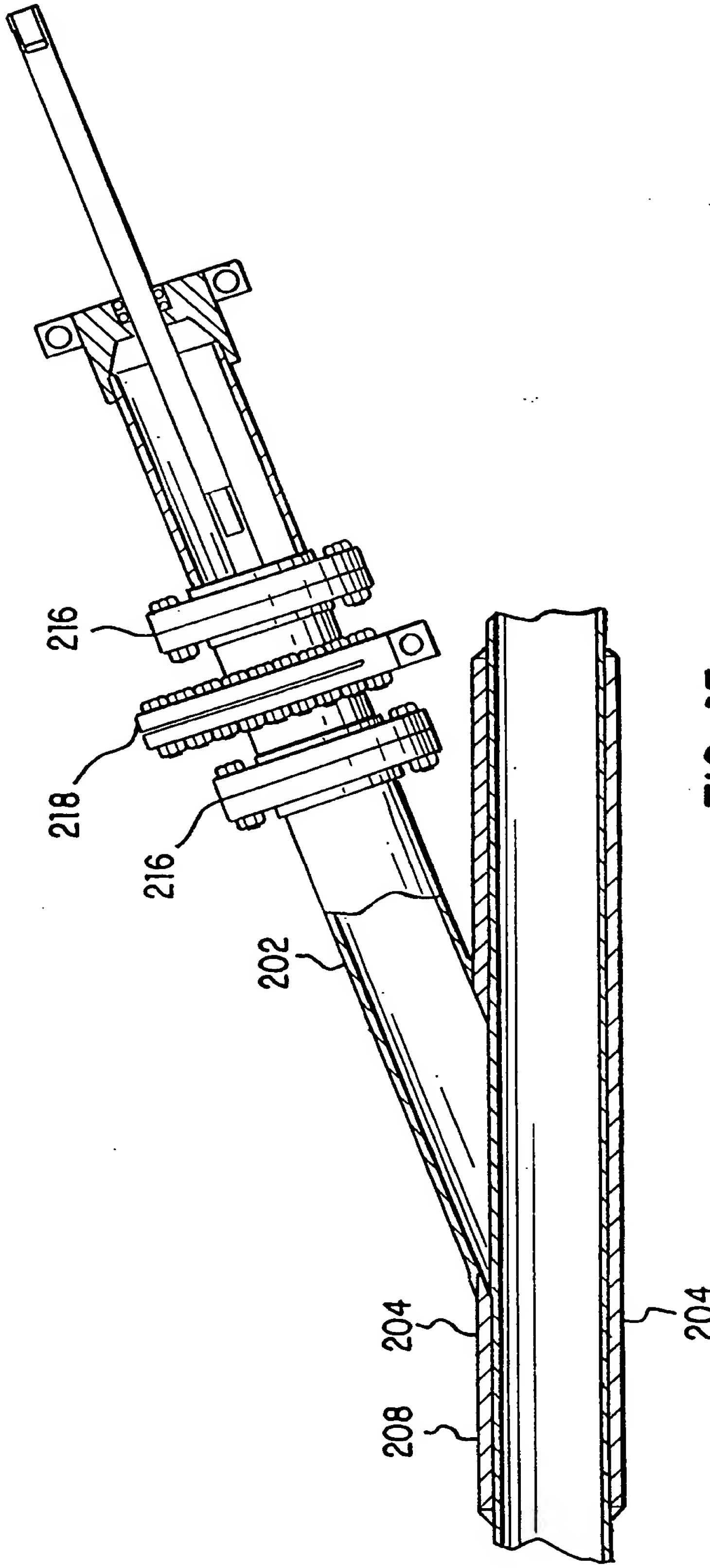

FIG. 15

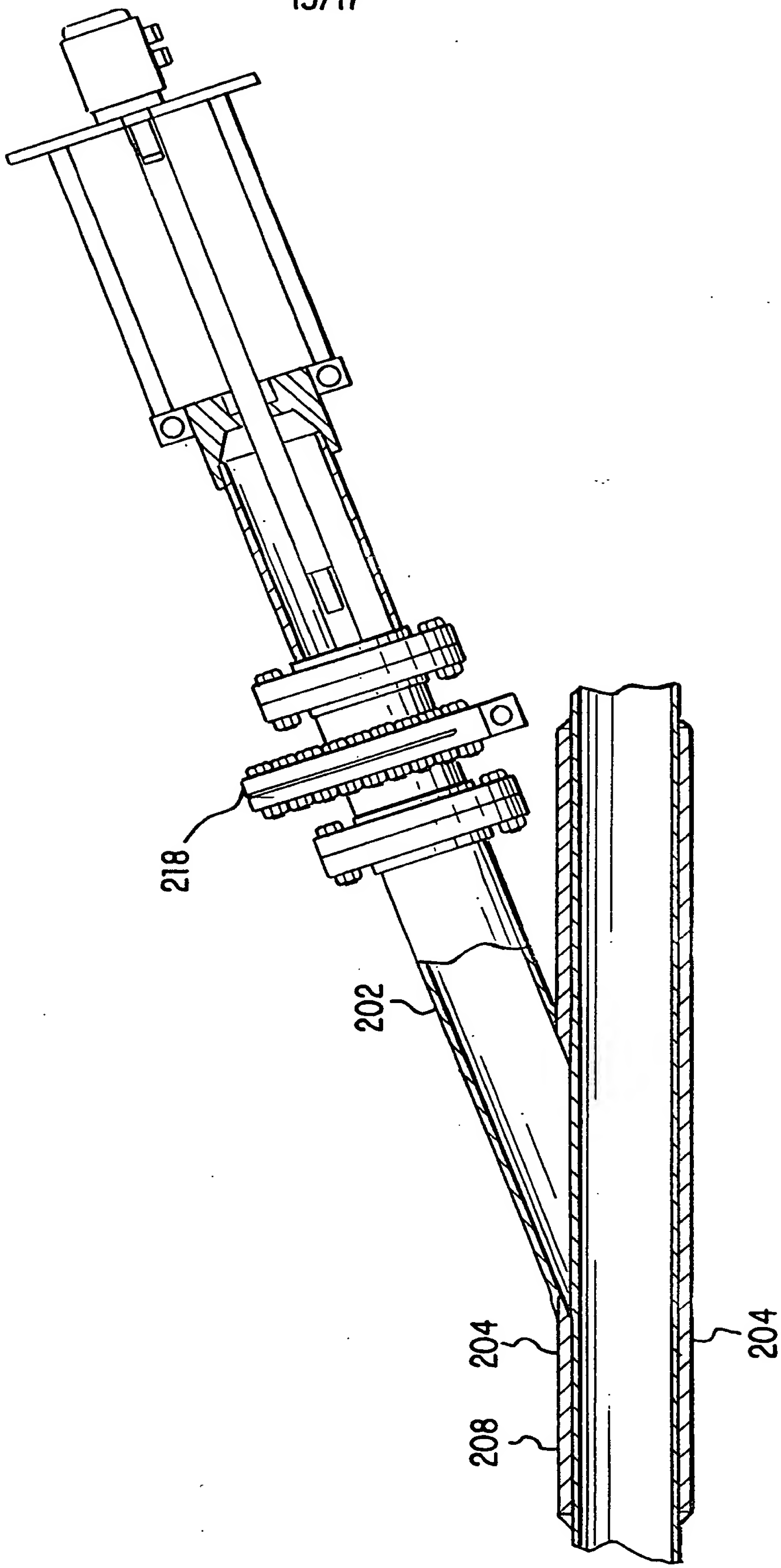

FIG. 16

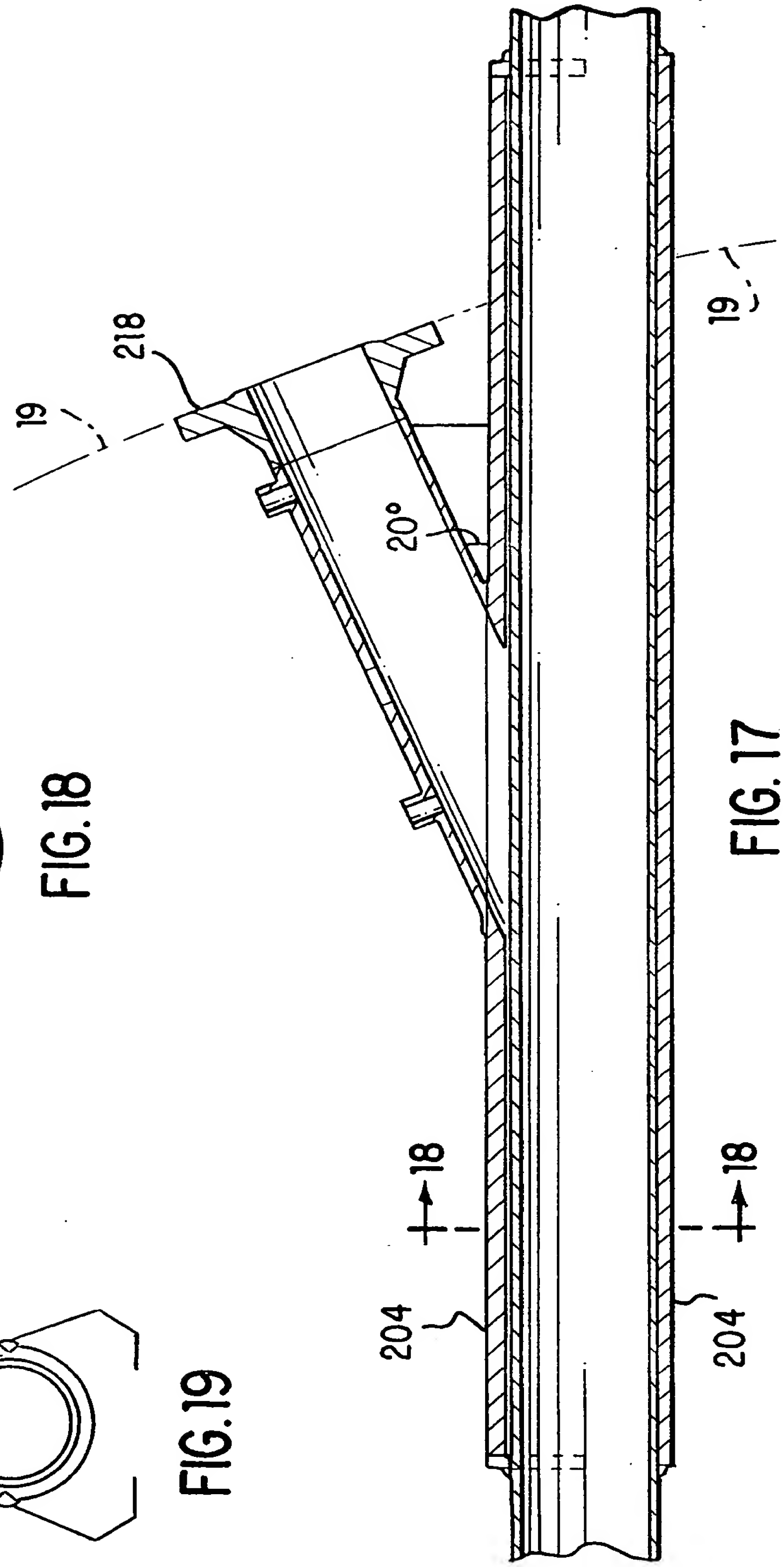

FIG.17

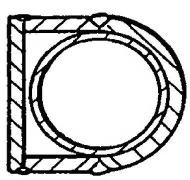
FIG.18

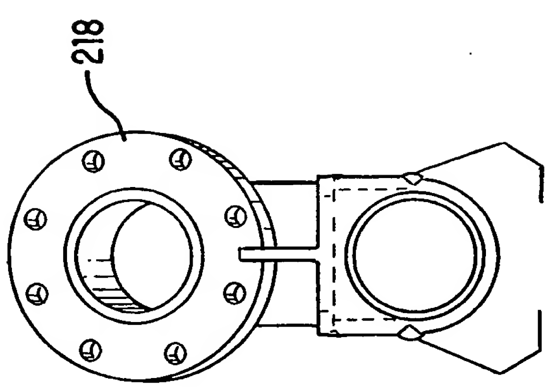

FIG.19

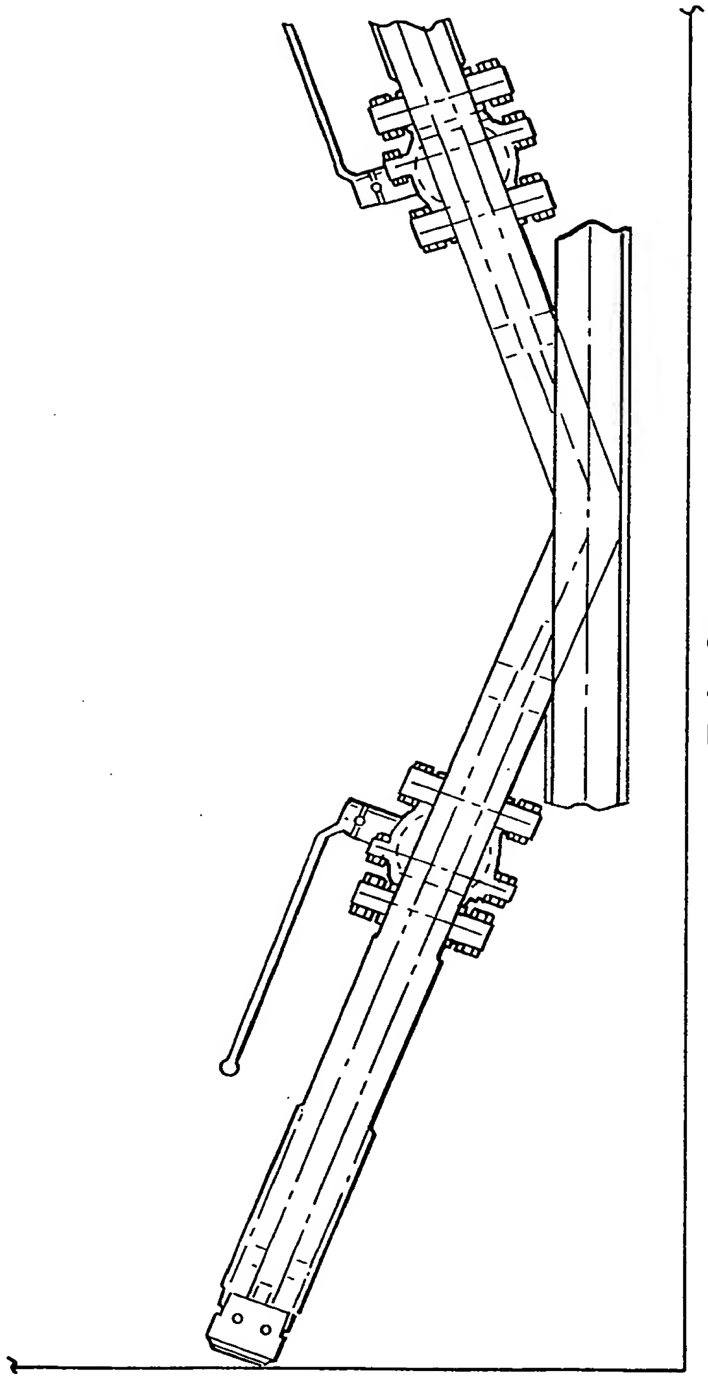

FIG. 20

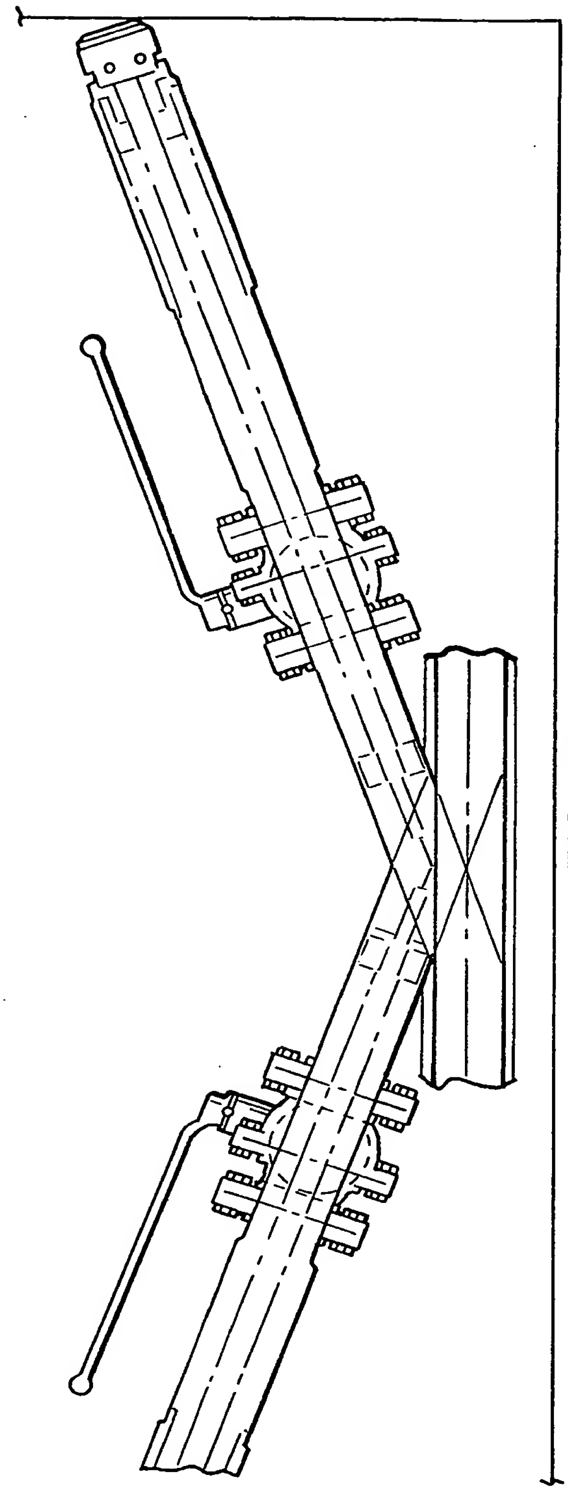

FIG. 21

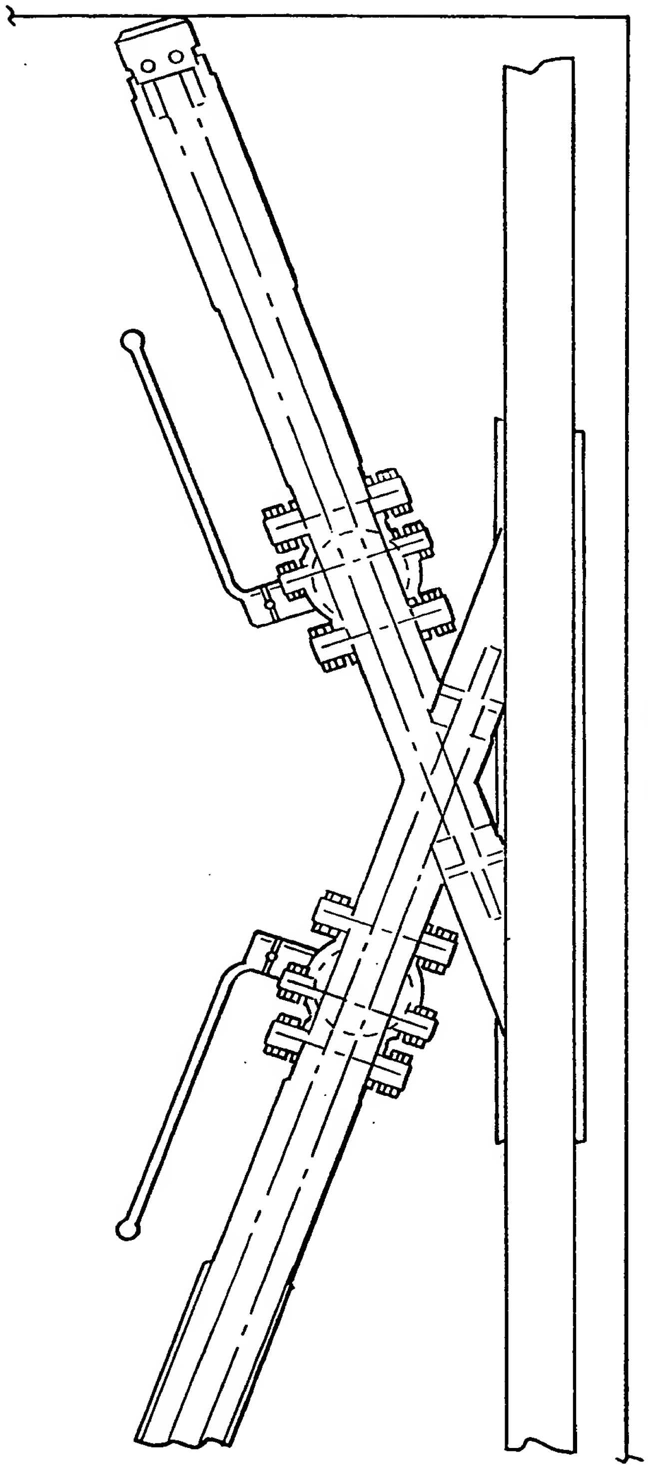

FIG. 22